National Aeronautics and
Space Administration

Space Weather and Natural Environments

Expert Design and Decision Support

Ensuring the robustness and reliability of systems in the extreme environments of space, whether for commercial or exploration applications, is a key challenge to mission success. Marshall's repository of space environment effects data is unique in the world, with engineers that have access to a range of test capabilities to support the design of new missions. Data is freely available to industry, partnerships are routinely formed offering test and consulting services, and other agencies frequently collaborate with Marshall's fundamental researchers in heliophysics to improve space weather forecasting and decision support capabilities.

The loss of spacecraft due to the environment can cost hundreds of millions of dollars. Marshall is home to decades of data captured worldwide to define those environments — from Earth's surface to deep space — and the Center provides the information and expertise it takes to design and fly a successful mission.

Designing for the Harsh Environments of Space

Wind, rain, and lightning in Earth's atmosphere impact launches and returning spacecraft, but the vacuum of space is the harshest environment, with meteoroids, cosmic rays, natural radiation belts, solar energetic particles, plasmas, and solar ultraviolet radiation.

At-A-Glance

Marshall Space Flight Center's capabilities reduce risks for the most challenging missions, whether in low Earth orbit (LEO) or deep space. The Center's capabilities and broad range of experience and expertise are unique in the world.

Marshall's unique expertise in space weather aids hardware designers in reducing risk.

Reducing Risks from Radiation Exposure

Marshall experts study sun-influenced space weather and energetic particle emissions from solar flares and other solar eruptions. They also provide data to environmental test experts who work directly with engineers to understand the material needs for a particular spacecraft and to replicate environments to test effects on those materials. Marshall interprets and analyzes data, such as spacecraft charging and ionizing radiation, to understand the environment and determine risks. This wealth of data is collected and made freely available.

Spacecraft charging, including both surface charging and internal dielectric charging, requires a variety of design mitigation techniques. Electrostatic discharge (ESD) from this charging can have consequences ranging from intermittent anomalous behavior to catastrophic failure. Ionizing radiation causes degradation in spacecraft materials and electronics over time, causing transient current pulses that can change information stored in computer memories, upsetting the operation of sensitive circuits, or even resulting in catastrophic damage and loss of electronic components.

The gap between science and engineering is bridged using measurements to answer specific questions and packaging or modeling the data to ensure that current and future aerospace vehicles are successful. Some of the models developed by Marshall include:

- L2 Charged Particle Environment (L2-CPE) Model evaluates the radiation dose on surface materials of spacecraft in orbit about the Sun-Earth L2 Lagrange point or when passing through distant regions of Earth's magnetotail.
- Chandra Radiation Model (CRM), developed for the Chandra X-ray Observatory program, provides low-energy proton flux for environments along a spacecraft trajectory, including the solar wind and magnetosheath outside Earth's magnetic field, and trapped particle environments within the magnetic field as a function of activity levels.
- A version of the NUMIT (numerical integration) internal charging code evaluates risks for ESD in materials exposed to energetic electron environments. The model has simulated static test environments, screened materials for long-term use in geostationary orbit, and simulated decades of interplanetary space exposure on cryogenic materials.

Marshall collects, develops, and disseminates radiation data required to design, manufacture, and operate more reliable, cost-effective spacecraft. In support of the International Space Station (ISS), the Center provides solar activity forecasts for operations personnel, captures and analyzes data to evaluate ESD risks and hazards to crew performing extravehicular activities (EVA), and provides annual and EVA-specific meteor shower forecasts. The Center also extends this experience to other programs such as the Launch Services Program (LSP). Marshall helps LSP engineering personnel evaluate ionizing radiation and spacecraft charging issues for NASA's unmanned launch vehicles.

Unique Facility Tests the Response of Space Environment Exposure

The Low Energy Electron and Ion Facility (LEEIF) located at Marshall is a joint research venture between NASA and seven research universities. LEEIF can expose spacecraft parts to ion beams of specific energy from specific directions to help calibrate the flight data. In 2012 and 2013, teams calibrated the Dual Ion Spectrometer flight sensors for the Magnetospheric Multiscale (MMS) mission planned in 2014. LEEIF is available for calibrating science instruments and is home to a large vacuum chamber for simulating space plasma.

Engineers at LEEIF calibrate instruments for testing in simulated space plasma environments.

Micrometeoroids and Orbital Debris Mitigation

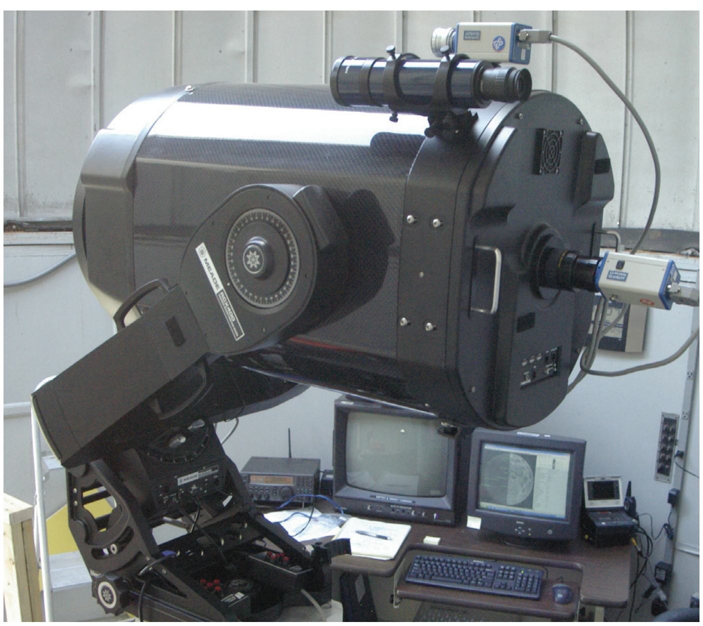
Spacecraft in LEO continually impact with micrometeoroids and with orbital debris (MMOD), which, at high speeds, can cause mechanical or electrical damage. MMOD data transitioning research to applications that benefit space system design and operation increases understanding of the universe and improves space systems.

Modeling:

- Meteoroid Stream Model forecasts meteor showers for Earth and Earth-orbiting spacecraft.
- Meteoroid Engineering Model (MEM) identifies sporadic radiants with real sources of meteoroids, such as comets; uses a physics-based approach to yield accurate fluxes and directionality for interplanetary spacecraft anywhere from .2 AU to 2 AU; and obtains velocity distributions from theory and validates these against observation.

Missions:

- Mars Atmosphere and Volatile EvolutioN (MAVEN) — Marshall experts created models for the MAVEN mission to Mars to help determine risks and mitigation strategies for meteor showers occurring near the potential launch dates.
- Chandra X-ray Observatory — Chandra required a radiation model designed by Marshall to tell operators when to perform science and when to protect X-ray sensors. Marshall personnel also provide custom meteor shower forecasts to aid in operations planning.
- James Webb Space Telescope — Marshall developed the spacecraft charging, surface radiation, and meteoroid environment definitions for the James Webb Space Telescope.



Automated Lunar and Meteor Observatory (ALAMO)

Marshall is home to NASA's Meteoroid Environment Office (MEO) that operates six all-sky camera systems in the southeastern United States and two in New Mexico for the detection of bright meteors and fireballs. ALAMO makes Earth-based telescopic observations of the dark portion of the moon to establish the speed and sizes of large meteoroids (greater than 100 grams) striking the lunar surface.

In addition to the shower meteoroids, the MEO focuses on the sporadic random environment, which is a continuous risk that must be mitigated by appropriate design leading to significant engineering challenges. A designer must determine how much spacecraft shielding is necessary for a spacecraft and what parts of the spacecraft will be most exposed during its mission. The MEO is well known for studying the shower environment, providing forecasts so spacecraft operators can reorient vehicles to point sensitive equipment away from the radiant (direction of origin), skew solar panels edge-on to minimize the cross sectional area presented, and close shutters to protect sensitive optics.

A Prototype To Reduce Risk of Neutron Radiation Exposure

Sending astronauts farther into our solar system than ever before will require advanced instruments designed for monitoring and detecting radiation in space vehicles and habitats. Marshall tackled this problem with a renewed focus on understanding radiation in space environments. Scientists and engineers at Marshall developed a prototype for the Advanced Neutron Spectrometer (ANS) instrument in close collaboration with Johnson Space Center (JSC) and other NASA centers. Marshall developed the prototype instrument in only 11 months. Radioactive sources and exposures to high-energy protons at Indiana University Cyclotron Facility were used to evaluate the performance of the ANS.

The ANS is an instrument designed to monitor neutrons; the aim is to build a new tool to protect astronauts as they explore new destinations. The ANS can be used to detect the levels of radiation in the spacecraft or habitat so that astronauts can employ techniques to minimize their exposure.

By working closely with JSC and other NASA centers, Marshall has been able to make great strides on some key radiation protection issues that include the ANS prototype. The goal is to continue this work to improve the instrument performance and our radiation monitoring capabilities to reduce risks when exploring new destinations.

The MEO provides meteoroid forecasts to reduce risk of mission or spacecraft loss.

Getting There and Back Safely: Ascent, Re-entry, Descent

From launch to landing, Marshall experts have decades of experience in delivering data to increase spacecraft survivability. Marshall models have a wide range of applications, including systems design, performance analysis, operations planning for aerobraking, entry descent and landing, and aerocapture. Models include:

- **Marshall Engineering Thermosphere** (MET) calculates kinetic temperature of the neutrals, number densities of individual species, and total mass density and pressure to help predict atmospheric drag; important to lifetime estimates, orbit determination and tracking, attitude dynamics, and re-entry prediction.
- **Earth Global Reference Atmospheric Model** (Earth-GRAM) provides density, temperature, pressure, winds, and selected atmospheric constituent concentrations, from the surface of Earth to orbital altitudes, as a function of geographic position and time of year.
- **Mars Global Reference Atmospheric Model** (Mars-GRAM) is an engineering-level atmospheric model widely used for diverse mission applications. Mars GRAM outputs include density, temperature, pressure, winds, and selected atmospheric constituents. Applications include systems design, performance analysis, and operations planning for aerobraking, entry descent and landing, and aerocapture.

Support such as defining, collecting, and evaluating data results in risk reduction for even the most challenging missions. Missions supported include:

- **Space shuttle** — During launch countdown, Marshall evaluated the atmospheric conditions that could impact the vehicle's steering commands. Marshall mission-critical personnel were on console in the Huntsville Operations Support Center for all launches.
- **Space Launch System** (SLS) — Marshall is working with the SLS team to define the natural environments the vehicle and the Orion Multi-Purpose Crew Vehicle will encounter. SLS, managed by Marshall for NASA's Human Exploration Office, is scheduled for its first unmanned test launch in late 2017 from Kennedy Space Center (KSC).
- **Mars Science Laboratory** (MSL) — Marshall supported the Jet Propulsion Laboratory using Mars-GRAM to assess the laboratory's landing capabilities, aiding in the landing site selection process as well as the entry, descent, and landing at Gale crater.
- **Orion Multi-Purpose Crew Vehicle** — Marshall data drove the design of the wave pool built for testing Orion ocean splashdowns, which winds and waves can affect.

New Doppler Radar Wind Profiler Will Help Mitigate Launch Risks

Marshall's role in spacecraft survivability starts at the ground, since getting safely through Earth's atmosphere is the first critical step in any space mission.

The Center is looking forward to a new 50-megahertz (MHz) Doppler Radar Wind Profiler (DRWP) that goes online in late 2014 at Kennedy Space Center (KSC) — well before the first launch of the SLS, America's next advanced heavy-lift rocket, now in development at Marshall.

Marshall built a new database of upper air winds over the KSC area by archiving the 12 years of wind profiles from the existing 50-MHz DRWP. This new database is being used in the design of the SLS. In the past, designers and operators relied on upper atmospheric wind measurements from weather balloons. However, balloons cannot capture rapid changes in winds that can be observed by the wind profiler. Data archived from the 50-MHz DRWP reduce uncertainty in the design of a new launch vehicle, such as the SLS, making it safer.

By using archived data from the older DRWP during the design phase and real-time data from the new DRWP on launch day, the SLS and other commercial launch vehicles will have greater safety and reliability when encountering upper atmospheric winds on their way to space.

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George C. Marshall Space Flight Center
Huntsville, AL 35812
www.nasa.gov/marshall

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